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(54) Radio-frequency power amplifier device

Leistungsverstärker für Hochfrequenzsignale

Amplificateur de puissance pour signaux RF

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(56) References cited:
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EP-A- 0 412 392
EP-A- 0 472 330
US-A- 4 392 245

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Description

BACKGROUND OF THE INVENTION

The present invention relates to a radio-frequency power amplifier device used in a radio transmitter, and in particular to a radio-frequency power amplifier device in which the output power is automatically controlled to be constant.

Fig. 4 is a block diagram showing a prior-art radio-frequency power amplifier device for receiving and amplifying a radio-frequency input signal 1 (hereafter referred to as RF input signal). As illustrated, it comprises a radio-frequency power amplifier 2 having a gain control terminal 3 for varying the gain of the power amplifier 2 and producing an amplified radio-frequency output signal (hereinafter referred to as RF output signal) 4, a coupling capacitor 5 for extracting part of the RF output signal 4, a detector circuit 6 comprised of diodes and a smoothing circuit for detecting the radio-frequency signal and producing a detected voltage output 7, a reference voltage setting circuit 8 for outputting a reference voltage 8a corresponding to the power level that has been set in accordance with a power level switch control signal 10a supplied from a controller 10 and used for switching the output power, and a comparator/low-pass filter circuit 9 comparing the detected voltage 7 with the reference voltage 8a and having a low-pass filter (LPF) characteristics.

In operation, the RF input signal 1 is power-amplified by the power amplifier 2 to become the RF output signal 4. Part of the RF output signal 4 is input to the detector circuit 6 via the coupling capacitor 5. The detector circuit 6 performs the peak-detection, and outputs the detected voltage 7 corresponding to the magnitude of the RF output signal 4. The comparator/LPF circuit 9 compares the detected voltage 7 with the reference voltage 8a to detect their difference or error between them, and passes the error signal through the LPF to smooth it, and then outputs it. The error signal 9a output from the comparator/LPF circuit 9 is input to the gain control terminal 3 provided on the power amplifier 3.

The path from the coupling capacitor 5 through the comparator/LPF circuit 9 to the gain control terminal 3 forms a negative feedback circuit. When the RF output signal 4 becomes larger than the target value, the detected voltage 7 increases and a negative error signal is created to reduce the gain of the power amplifier 2. When the RF output signal 4 becomes smaller, a positive error signal is created, and the gain of the power amplifier 2 is increased. In this way, the RF output power is automatically controlled to be constant.

The reference voltage setting circuit 8 has a power level switching input terminal for permitting the target value to be set from the controller 10. By such setting, different set voltages can be output. Accordingly, any one of a plurality of output power values (power levels), from a low-power output to a high-power output, that is set by means of the controller 10, can be selected.

Because the prior-art radio-frequency power amplifier device is configured as described above, when the output power (power level) is switched, the magnitude of the signal input to the detector circuit 6 also varies. Accordingly, the detector circuit 6 must have a wide dynamic range to cope with all the power levels. As a result, when a low-power output is set, the detected voltage 7 is minute, and the temperature variation of the forward-voltage of the detector diodes forming the detector circuit 6 gives a large influence on the output power value.

EP 0412392 relates to a radio frequency power amplifier in which an attenuator is provided for allowing a single setting of the output power from the amplifier. This arrangement thus increases the range of output power applied to the detector.

US P 4,392,245 describes a radio transmitter in which the output power from a directional coupler is attenuated by varying the coupling coefficient of that directional coupler.

SUMMARY OF THE INVENTION

The present invention has been made to eliminate the problems described above, and its object is to provide a radio-frequency power amplifier device enabling a variable (switching) control from a low power to a high power without widening the dynamic range of the detector circuit, and reducing the temperature variation in the output value at the time of low power output.

According to the present invention there is provided a radio-frequency power amplifier device as set out in appended Claim 1.

The radio-frequency power amplifier device according to the invention is provided with an extracting means for maintaining the input to the detector circuit at a constant level, and the input level to the detector circuit is not varied even if the power level is switched.

As the input to the detector circuit is maintained at a constant level by the function of the extracting means, the diodes in the detector circuit perform the detection at the same operating point regardless of the output power. As opposed to the prior art, wide dynamic ranges are not required, and a sufficient detected voltage is obtained even at the time of low-power output, so the effect of the temperature characteristics of the diode forward voltage on the output is reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing a radio-frequency power amplifier device of a first embodiment of the invention.

Fig. 2 is a block diagram showing a radio-frequency power amplifier device of another embodiment of the invention.

Fig. 3 is a block diagram showing a radio-frequency

power amplifier device of a further embodiment of the invention.

Fig. 4 is a block diagram showing a radio-frequency power amplifier device in the prior art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiment 1

A first embodiment, Embodiment 1, of the invention will now be described with reference to Fig. 1. The parts which correspond to those in Fig. 4 are given identical reference numerals, and their description will be omitted.

The Embodiment 1 differs from the prior-art device in that a variable attenuator 11 is provided between the coupling capacitor 5 and the detector circuit 6 and having its attenuation controlled in accordance with the power level switch control signal 10a. Another variable attenuator 12 is provided between the comparator/LPF circuit 9 and the gain control terminal 3 and having its attenuation controlled by the power level switch control signal 10a. In place of the reference voltage setting circuit 8 in Fig. 4, which outputs the reference voltage 8a corresponding to the power level that has been set in accordance with the power level switch control signal 10a, a reference voltage setting circuit 18 generating a reference voltage 18a of a fixed value.

The gain control terminal 3 constitutes the output power adjusting means, the capacitor 5 constitutes the coupling means, the detector circuit 6 constitutes a radio-frequency detecting means, the comparator/LPF circuit 9 constitutes a comparing and smoothing means, and the variable attenuator 12 constitutes a feedback gain control means.

In operation, the RF input signal 1 is power-amplified by the power amplifier 2 to become the RF output signal 4. As in the prior art, part of the RF output signal 4 is extracted by means of the coupling capacitor 5, and subjected to the below-described processing, and a negative feedback is given to the gain control terminal 3 thereby to stabilize the output power.

The signal extracted by the coupling capacitor 5 is proportional to the RF output signal 4. The signal is input to the variable attenuator 11. The attenuation of the variable attenuator 11 is so controlled as to be large at the time of high power output and to be small at the time of low power output, so that the output of the variable attenuator 11 is at a constant level (within an invariable range) regardless of the output power (power level) of the radio-frequency power amplifier device.

The detector circuit 6 detects the output of the variable attenuator 11 and outputs the detected voltage 7. The magnitude of the input radio frequency signal to this detector circuit 6 is at a constant level regardless of the power level by virtue of the variable attenuator as described above, except for variations due to error. Accordingly, the detected voltage 7 is expected to be at a constant level regardless of the power level. As a result, the reference voltage 18a for use in comparison with the detected voltage 7 need not be switched according to the target power level. The reference voltage 18a and the detected voltage which are at a constant level regardless of the power level are compared and smoothed at the comparator/LPF circuit 9, to obtain an error signal 9a. The error signal 9a is fed back to the gain control terminal 3 through the variable attenuator 12 having its attenuation varied (switched) in accordance with the power level switch control signal 10a.

The variable attenuator 12 is operated such that the overall gain of the negative feed back circuit does not vary with the power level. In accordance with the power level switch control signal 10a, the attenuation of the variable attenuator 12 as a feedback gain control means is set small at the time of high power output when the attenuation of the variable attenuator 11 is set large, and is set large at the time of low power output when the attenuation of the variable attenuator 11 is set small.

In the prior-art example described earlier, the magnitude of the input to the detector circuit 6 differs depending on the power level, and a problem was encountered in connection with the dynamic range of the detector circuit 6 wherein at the time of high power input, the detector diodes in the detector circuit 6 may be overloaded, and at the time of low power output a sufficient detected voltage 7 is not obtained. In the Embodiment 1, the input to the detector circuit 6 is at a constant level regardless of the power level, and the wide dynamic range which was required for the detector circuit of the prior art is not necessary. In the prior-art example, at the time of lower power output, a sufficient detected voltage 7 was not obtained, and the temperature variation of the forward voltage drop of the detector diodes superimposed thereon is not negligible, and the temperature variation of the output power is larger than when the power output is high. In contrast, in the Embodiment 1, at the time of low power output, the detector circuit 6 is supplied with a signal of a sufficient magnitude, so the temperature variation at the time of the low power output is restrained.

Embodiment 2

Fig. 2 is a block diagram showing a second embodiment, Embodiment 2, of the invention. The parts corresponding to those in Fig. 1 are given identical reference numerals.

The Embodiment 2 differs from the Embodiment 1 in that, in place of the coupling capacitor 5 and the variable attenuator 11, a variable coupling circuit 15 is provided as a means of coupling-coefficient-variable coupling means. It has a coupling coefficient varied by the power level switch control signal 10a, and extracts part of the output power of the power amplifier 2 and applies it to the detector circuit 6.

In the Embodiment 1, part of the output power is extracted with a fixed coupling coefficient and attenuated by means of the variable attenuator 11, so that the input to the detector circuit 6 is maintained at a constant level against the power level switching. In the embodiment 2 of Fig. 2, the variable coupling circuit 15 is used so that the coupling coefficient itself is varied (switched). That is, the coupling coefficient is made small at the time of high power output and is made large at the time of low power output, so that the input to the detector circuit 6 is maintained at a constant level regardless of the power level.

Other parts operates in the same way as in the Embodiment 1 and the Embodiment 2 has the same effects as the Embodiment 1.

Embodiment 3

Fig. 3 is a block diagram showing a further embodiment, Embodiment 3, of the invention. In the Embodiments 1 and 2 shown in Fig. 1 and Fig. 2, the variable attenuator 11 or the variable coupling circuit 15 are provided such that the signal input to the detector circuit 6 is maintained exactly at a constant level, i.e., within a range which is invariable against the power level switching. When the width of the variation is very large, the devices are difficult to configure or are expensive. In the embodiment 3 of Fig. 3, the variable attenuator 11 operates so that the variation in the output when the power level is switched is restrained or reduced compared with the input, but not necessarily maintained within an invariable range. In other words, the range in which the input to the detector circuit may vary but the width of the variation is smaller than in the prior art. To cope with the variation in the detected voltage 7, a reference voltage setting circuit 8 having a variable reference voltage 8a is provided, and is switched in accordance with the power level switch control signal 10a.

In the Embodiment 3, since the range of operation of the detector circuit 6 is narrow compared with the prior art example, effects similar to those obtained in the Embodiments 1 and 2 are obtained. That is, the range required of the detector circuit may be narrower than in the prior art (although wider than in the Embodiments 1 and 2). Moreover, the reduction in the signal supplied to the detector circuit 6 at the time of low power output is restrained, so the effect of the temperature variation is reduced.

In the Embodiments 1 to 3, the feedback control signal is fed back to the gain control terminal 3 provided on the power amplifier 2, but some other methods may be employed. For instance, an additional variable attenuator may be provided in front of the power amplifier 2, and may be controlled to adjust the output power.

In the Embodiments 1 to 3, the variation of the gain of the feedback circuit is made by means of the variable attenuator 12, but some other methods may be employed. For example, the gain of the comparator/LPF circuit 9 may be switched.

As has been described, according to the invention, a variable attenuator or a coupling-coefficient-variable coupling means is provided in front of the detector circuit, and the variation in the input to the detector circuit is restrained or reduced even when the output power value is switched, and the range of operation of the detector circuit is limited. As a result, it is possible to obtain a device in which the dynamic range required of the detector circuit is narrowed, and the temperature variation of the output power at the time of the low power output is reduced.

Claims

1. A radio-frequency power amplifier device for producing an output whose magnitude is switched in accordance with a power level switch control signal, comprising:

a radio-frequency power amplifier (2) receiving an input and providing a power-amplified output (4);
an extracting means (5,11,15) for extracting part of the output power at the output of the radio-frequency power amplifier, and outputting a signal having a magnitude indicative of the magnitude of the output of the power amplifier, said extracting means having a first gain varied in accordance with the power level switch control signal;
a high-frequency detecting means (6) detecting the output of the extracting means;
a comparing and smoothing means (9) comparing the detected voltage of the high-frequency detecting means (6) with a predetermined reference voltage, and smoothing the difference;
a feedback gain control means (12) connected to receive the output of the comparing and smoothing means, said feedback gain control means having a second gain varied in accordance with the power level switch control signal; and
an output power adjusting means for negative feedback controlling the output power of the power amplifier (2) in accordance with the output of the feedback gain control means.

2. The device of claim 1, wherein said extracting means comprises:

a coupling means for extracting part of the output power of the radio-frequency power amplifier and outputting a signal corresponding to the magnitude of the output of the power amplifier; and
a variable attenuator receiving the output signal

from the coupling means, and having its attenuation varied in accordance with the power level switch control signal.

3. The device of claim 1, wherein said extracting means comprises a coupling-coefficient-variable coupling means having a coupling coefficient controlled in accordance with the power level switch control signal.

4. The device of claim 1, wherein said extracting means controlling the magnitude of its output signal so as to be at a constant level regardless of the switching of the power level of the output of the device.

5. The device of claim 1, further comprising a means for varying the reference voltage in accordance with the power level switch control signal.

6. The device of claim 5, wherein said extracting means controls the magnitude of its output signal such that its variation with the switching of the power level of the output of the device is reduced.

7. The device of claim 1, wherein said extracting means, said high-frequency detecting means, said comparing and smoothing means, said feedback gain control means and said output power adjusting means form a feedback loop to control the gain of the power amplifier in accordance with the output of the power amplifier; and

said feedback gain control means (12) is controlled in accordance with the power level control signal in such a manner that the overall gain of the feedback loop is substantially constant.

Patentansprüche

1. Radiofrequenz-Leistungsverstärkervorrichtung zum Erzeugen eines Ausgangssignals, dessen Größe in Übereinstimmung mit einem Leistungspegel-Schaltsteuersignal schaltbar ist, welche aufweist:

einen Radiofrequenz-Leistungsverstärker (2) zum Empfangen eines Eingangssignals und zum Liefern eines leistungsverstärkten Ausgangssignals (4);
eine Extraktionseinrichtung (5, 11, 15) zum Extrahieren eines Teils der Ausgangsleistung am Ausgang des Radiofrequenz-Leistungsverstärkers und zum Ausgeben eines Signals mit einer Größe, welche die Größe des Ausgangssignals des Leistungsverstärkers anzeigt, wobei die Extraktionseinrichtung eine erste Verstärkung aufweist, welche in Übereinstimmung mit dem Leistungspegel-Schaltsteuersignal variabel ist;
eine Hochfrequenz-Erfassungseinrichtung (6) zum Erfassen des Ausgangssignals der Extraktionseinrichtung;
eine Vergleichs- und Glättungseinrichtung (9) zum Vergleichen der erfaßten Spannung der Hochfrequenz-Erfassungseinrichtung (6) mit einer vorbestimmten Referenzspannung und zum Glätten der Differenz;
eine Rückkopplungsverstärkungs-Steuereinrichtung (12), welche derart angeschlossen ist, daß sie das Ausgangssignal der Vergleichs- und Glättungseinrichtung empfängt, wobei die Rückkopplungsverstärkungs-Steuer-einrichtung eine zweite Verstärkung aufweist, welche in Übereinstimmung mit dem Leistungspegel-Schaltsteuersignal variabel ist; und
eine Ausgangsleistungs-Einstelleinrichtung zur negativen Rückkopplungssteuerung der Ausgangsleistung des Leistungsverstärkers (2) in Übereinstimmung mit dem Ausgangssignal der Rückkopplungsverstärkungs-Steuereinrichtung.

2. Vorrichtung nach Anspruch 1, wobei die Extraktionseinrichtung aufweist:

eine Kopplungseinrichtung zum Extrahieren eines Teils der Ausgangsleistung des Radiofrequenz-Leistungsverstärkers und zum Ausgeben eines Signals entsprechend der Größe des Ausgangssignals des Leistungsverstärkers; und
einen variablen Abschwächer zum Empfangen des Ausgangssignals von der Kopplungseinrichtung, welcher seine Abschwächung in Übereinstimmung mit dem Leistungspegel-Schaltsteuersignal variabel hat.

3. Vorrichtung nach Anspruch 1, wobei die Extraktionseinrichtung eine kopplungskoeffizienten-variable Kopplungseinrichtung aufweist, welche einen Kopplungskoeffizienten in Übereinstimmung mit dem Leistungspegel-Schaltsteuersignal steuerbar hat.

4. Vorrichtung nach Anspruch 1, wobei die Extraktionseinrichtung die Größe ihres Ausgangssignals derart steuerbar hat, daß es auf einem konstanten Pegel unabhängig vom Schalten des Leistungspegels des Ausgangssignals der Vorrichtung ist.

5. Vorrichtung nach Anspruch 1, welche weiterhin eine Einrichtung zum Variieren der Referenzspannung in Übereinstimmung mit dem Leistungspegel-Schaltsteuersignal aufweist.

6. Vorrichtung nach Anspruch 5, wobei die Extraktionseinrichtung die Größe ihres Ausgangssignals derart steuert, daß seine Variation mit dem Schalten des Leistungspegels des Ausgangssignals der Vorrichtung reduzierbar ist.

7. Vorrichtung nach Anspruch 1, wobei die Extraktionseinrichtung, die Hochfrequenz-Erfassungseinrichtung, die Vergleichs- und Glättungseinrichtung, die Rückkopplungsverstärkungs-Steuereinrichtung und die Ausgangsleistungs-Einstelleinrichtung eine Rückkopplungsschleife zum Steuern der Verstärkung des Leistungsverstärkers in Übereinstimmung mit dem Ausgangssignal des Leistungsverstärkers bilden; und

die Rückkopplungsverstärkungs-Steuereinrichtung (12) in Übereinstimmung mit dem Leistungspegel-Steuersignal derart steuerbar ist, daß die Gesamtverstärkung der Rückkopplungsschleife im wesentlichen konstant ist.

Revendications

1. Dispositif à amplificateur de puissance à haute fréquence pour la production d'un signal de sortie dont l'amplitude est commutée en fonction d'un signal de commande de commutation du niveau de puissance, comprenant :

un amplificateur de fréquence à haute fréquence (2) recevant un signal d'entrée et délivrant un signal de sortie (4) dont la puissance est amplifiée ;
des moyens d'extraction (5, 11, 15) pour extraire une partie de la puissance de sortie à la sortie de l'amplificateur de puissance à haute fréquence et délivrer un signal possédant une amplitude indicative de l'amplitude du signal de sortie de l'amplificateur de puissance, lesdits moyens d'extraction possédant un premier gain modifié en fonction du signal de commande de commutation du niveau de puissance ;
des moyens de détection à haute fréquence (6) détectant le signal de sortie des moyens d'extraction ;
des moyens de comparaison et de lissage (9) comparant la tension détectée des moyens de détection à haute fréquence (6) à une tension de référence prédéterminée, et lissant la différence ;
des moyens (12) de commande de gain de réaction connectés de manière à recevoir le signal de sortie des moyens de comparaison et de lissage, lesdits moyens de commande de gain de réaction possédant un second gain modifié en fonction du signal de commande de commutation du niveau de puissance ; et
des moyens de réglage de la puissance de sortie pour la commande, par contre-réaction de la puissance de sortie de l'amplificateur de puissance (2) en fonction du signal de sortie des moyens de commande du gain de réaction.

2. Dispositif selon la revendication 1, dans lequel lesdits moyens d'extraction comprennent :

des moyens de couplage pour extraire une partie de la puissance de sortie de l'amplificateur de puissance à haute fréquence et délivrer un signal correspondant à l'amplitude du signal de sortie de l'amplificateur de puissance ; et
un atténuateur variable, qui reçoit le signal de sortie provenant des moyens de couplage et dont l'atténuation est modifiée en fonction du signal de commande de commutation du niveau de puissance.

3. Dispositif selon la revendication 1, dans lequel lesdits moyens d'extraction comprennent des moyens de couplage à coefficient de couplage variable, dont le coefficient de couplage est commandé en fonction du signal de commande de commutation du niveau de puissance.

4. Dispositif selon la revendication 1, dans lequel lesdits moyens d'extraction commandent l'amplitude de leur signal de sortie de manière qu'elle soit à un niveau constant indépendamment de la commutation du niveau de puissance du signal de sortie du dispositif.

5. Dispositif selon la revendication 1, comprenant en outre des moyens pour modifier la tension de référence en fonction du signal de commande de commutation du niveau de puissance.

6. Dispositif selon la revendication 5, dans lequel lesdits moyens d'extraction commandent l'amplitude de leur signal de manière que sa variation lors de la commutation du niveau de puissance du signal de sortie du dispositif est réduite.

7. Dispositif selon la revendication 1, dans lequel lesdits moyens d'extraction, lesdits moyens de détection à haute fréquence, lesdits moyens de comparaison et de lissage, lesdits moyens de commande de gain par réaction et lesdits moyens de réglage de puissance de sortie forment une boucle de réaction servant à commander le gain de l'amplificateur de puissance en fonction du signal de sortie de l'amplificateur de puissance ; et

lesdits moyens (12) de commande de gain par réaction sont commandés en fonction du signal

de commande de niveau de puissance d'une manière telle que le gain global de la boucle de réaction est essentiellement constant.

FIG. 1

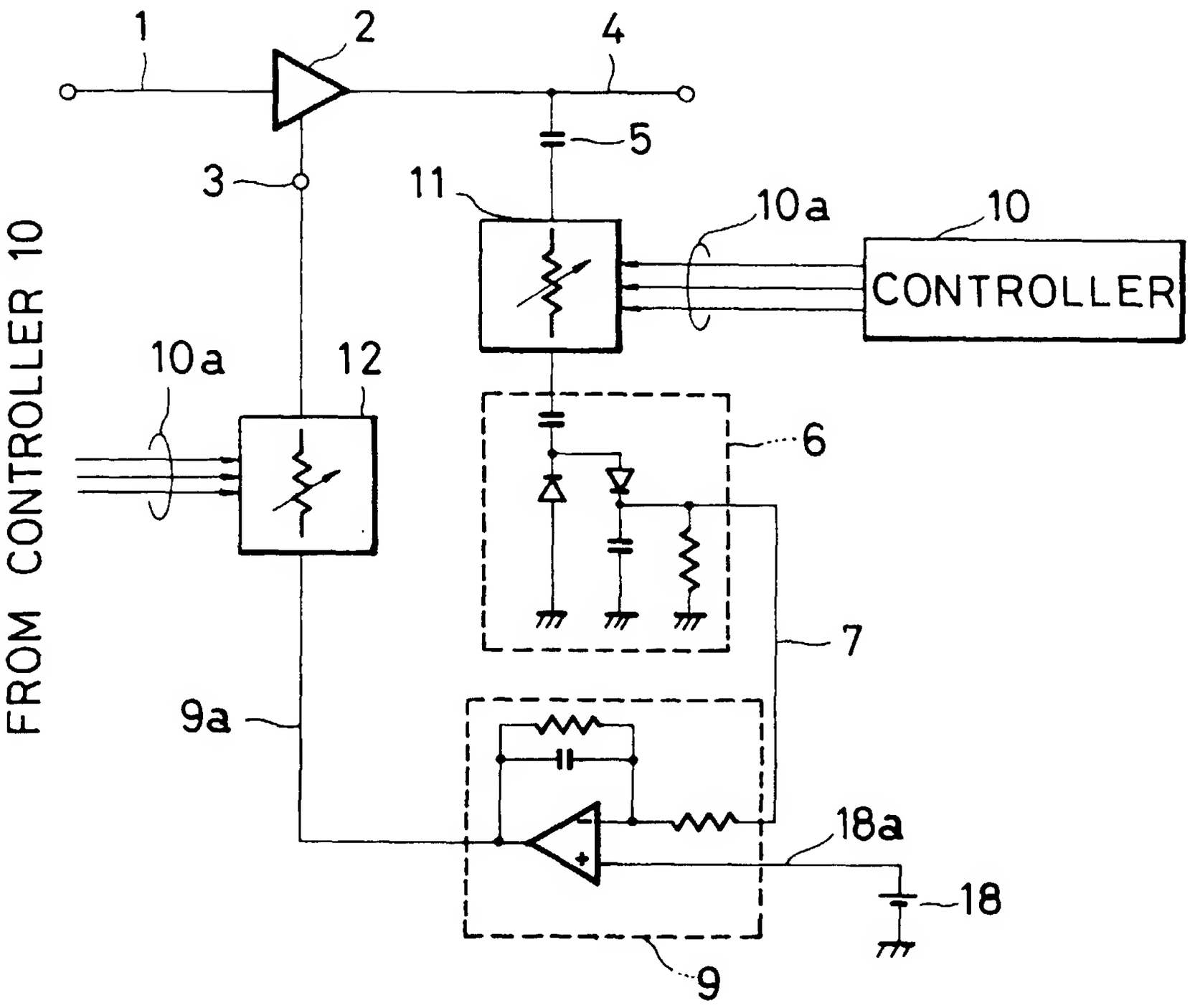
FROM CONTROLLER 10
1
2
4
5
3
11
10a
10
CONTROLLER
10a
12
6
7
9a
18a
18
9

FIG. 2

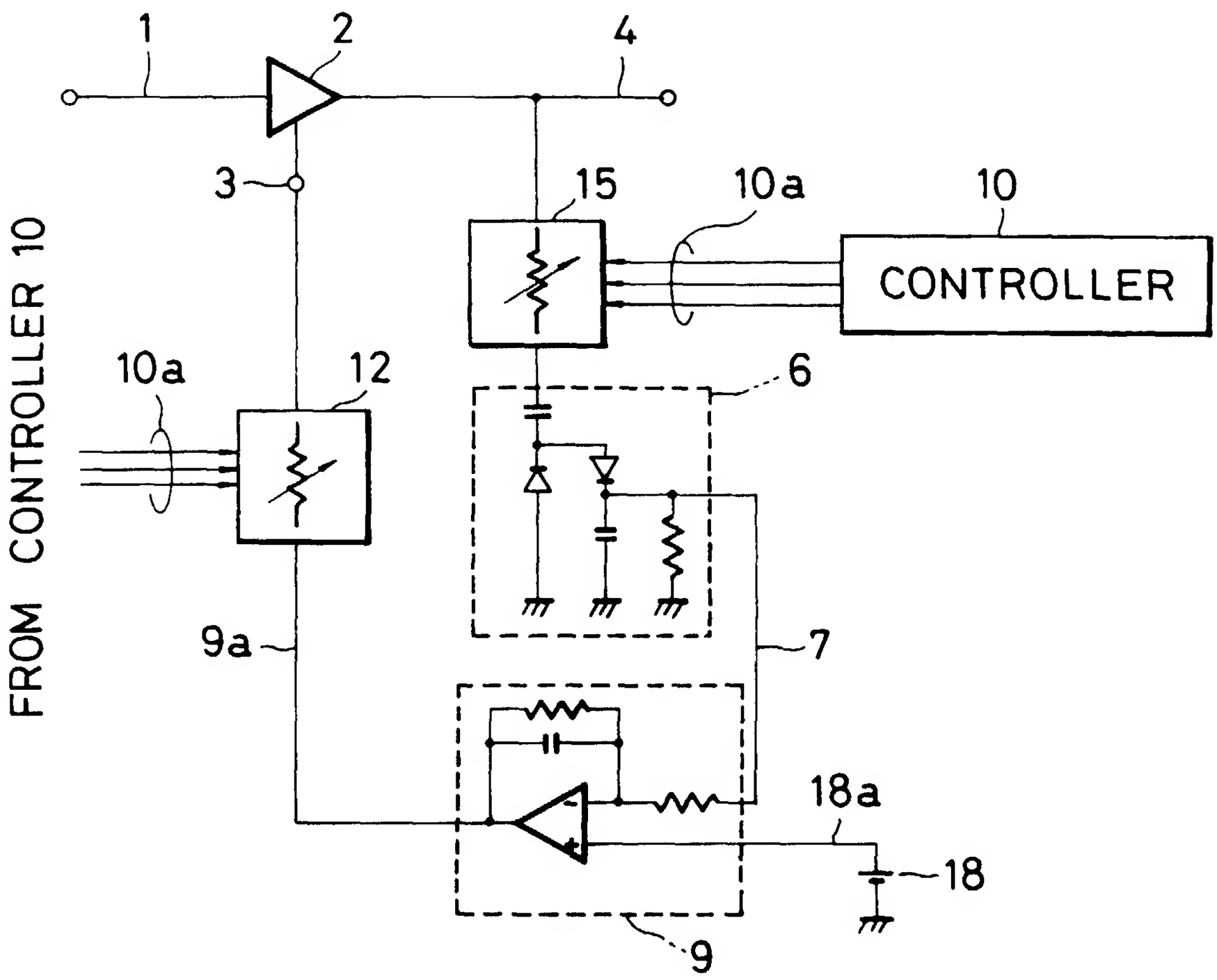
1
2
4
3
15
10a
10
CONTROLLER
FROM CONTROLLER 10
10a
12
6
9a
7
18a
18
9

FIG. 3

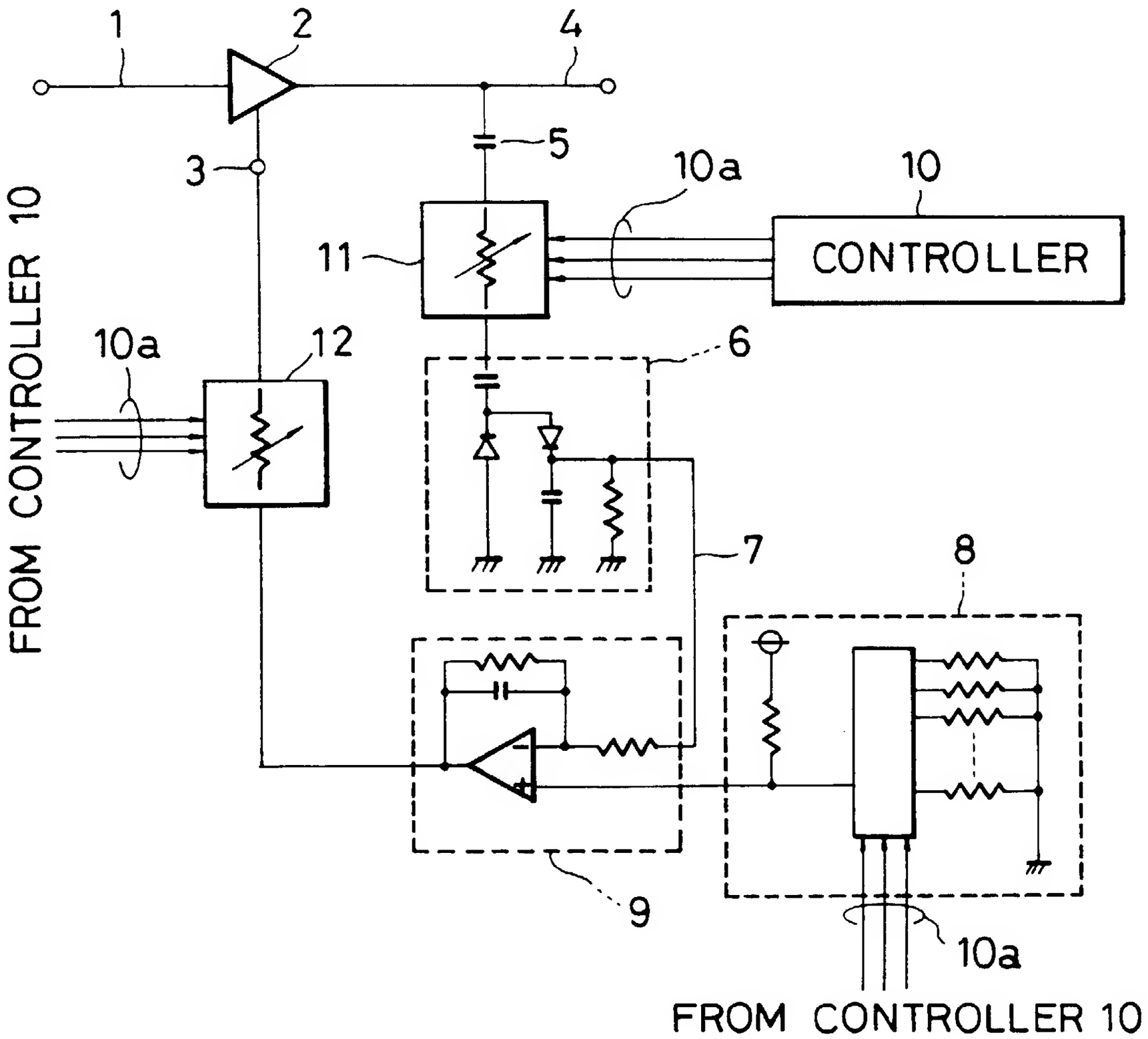
1
2
4
5
3
10a
10
11
CONTROLLER
FROM CONTROLLER 10
10a
12
6
7
8
9
10a
FROM CONTROLLER 10

FIG. 4